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Autonomous Rover-Based Scientific Investigations Using Invertable Mathematical Models

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The development of intelligent robotics, capable of autonomous scientific investigation, will greatly augment the exploration of Mars, and the rest of the Solar System and is a necessity for fulfilling NASA's Space Science, Human Exploration and Development of Space and Earth Science Enterprises. With the exploration of Mars, for example, advanced computing and robotic technology, specifically from the fields of machine learning and automated planning, allows a rover or cluster of rovers to carry out autonomous investigations into the most pressing questions of Martian geology and biology. We place on board the rovers mathematical models of geological processes, which generate distributions of rocks and minerals, as the rover knowledge database. We are developing on-board processing algorithms for future Mars rovers to automatically obtain rough classifications of accessible rocks and minerals from models of rock textures and analyses of multi-spectral images and point spectra. Ultimately, these and other algorithms (in the form of statistical models using stochastic parameterized grammars) will be used to formulate, test, and then either refine or discard hypotheses. Our initial approach utilizes models of meteorite impact, a process that generates an ejecta distribution that can be modelled. For example, impact and shock models predict three rough clast distributions, with (1) a zone close to the final crater rim of relatively lightly shocked material with distinct, overturned stratigraphy, beyond which is (2) a zone where ejecta are mixed as a result of higher ejecta impact velocities; and beyond this is (3) a zone of highly shocked material that originated from close to the point of impact. Using onboard instrumentation, rovers will map out the distribution of rocks and minerals in these zones, and using a sequence of increasingly sophisticated models of impact and ejecta emplacement, the pre-impact stratigraphy can be reconstructed.